

Transportation Behavioral Modelling: An Introduction

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Why are we interested in Travel Demand Modelling?

Forecast - Transportation Demand



Changes in the Attributes

Transportation system



People



User
Vehicle/ Carrier
Roadway/ Facility
Environment



Contents

- Introduction to four step model
- Choice Models
- Activity Based Modelling Approach



Introduction

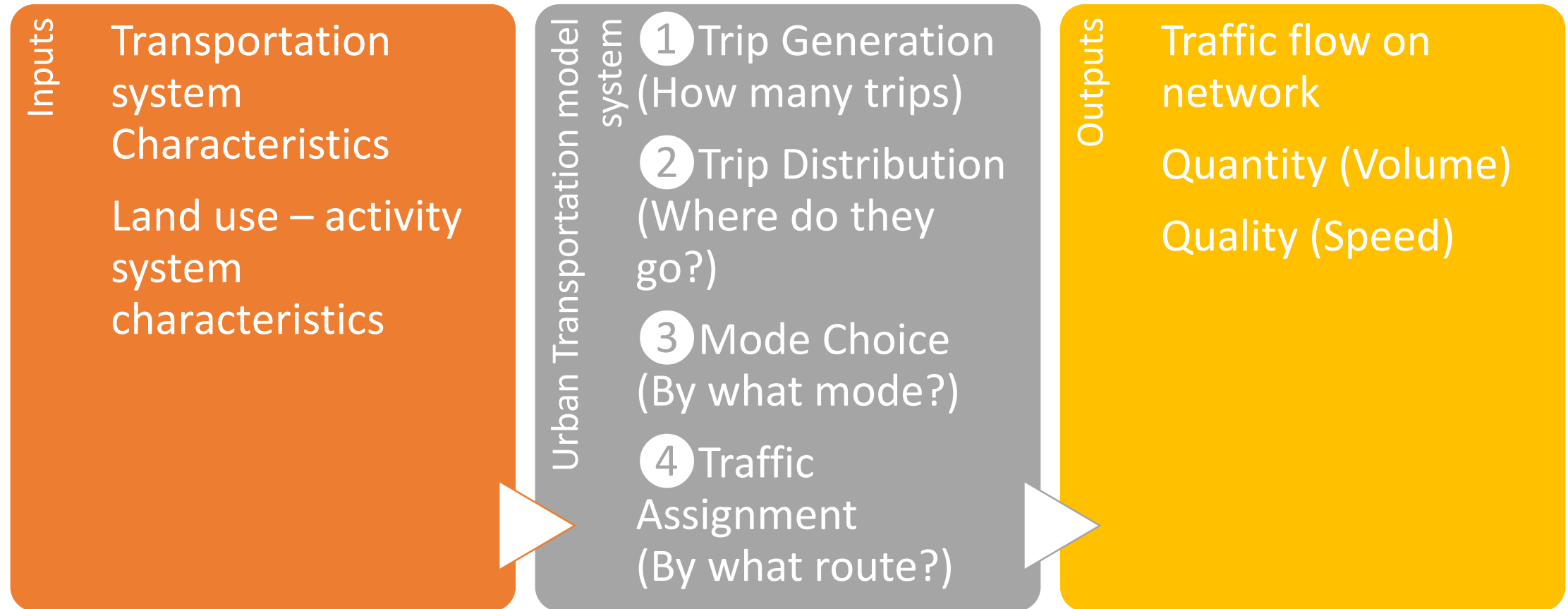
- Demand for Travel is a derived Demand
- Components of Transportation System
 1. User
 2. Vehicle/ Carrier
 3. Roadway/ Facility
 4. Environment
- Transportation systems problems
 1. Congestion
 2. Pollution
 3. Safety
 4. Parking



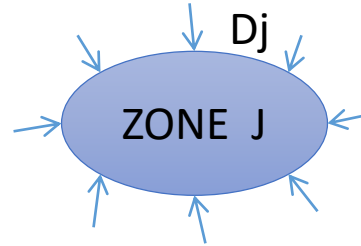
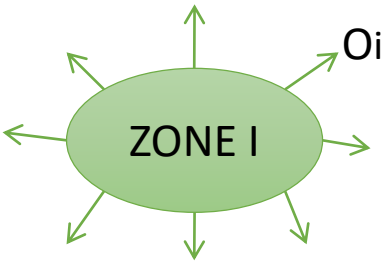
Four step model



Four step model



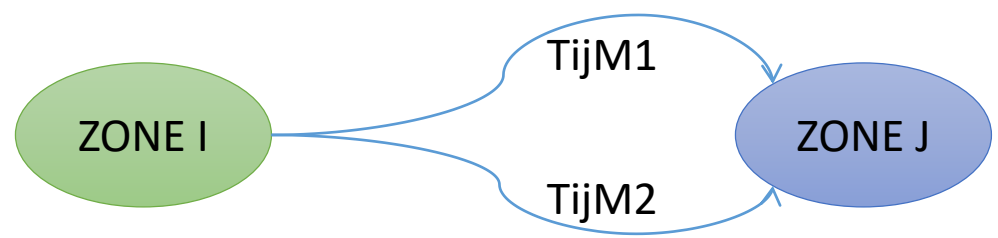
Four step model



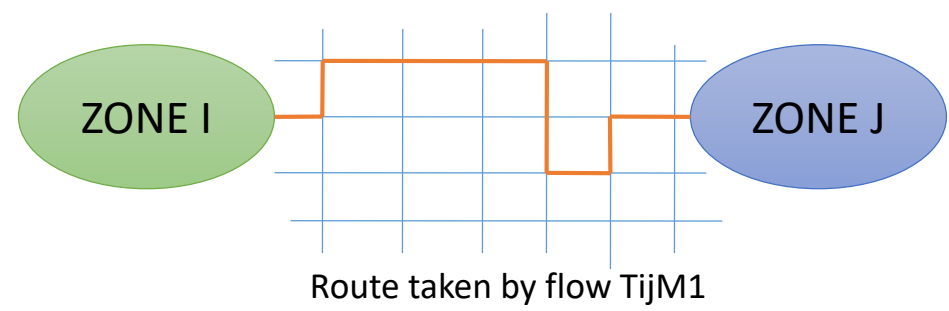
1
Trip generation



2
Trip distribution



3
Modal split



4
Assignment



Example

ZONE 1
Pi: 47;
Aj: 45

ZONE 2
Pi: 66;
Aj: 90

ZONE 3
Pi: 110;
Aj: 88

P_i

| Production | |
|------------|-----|
| 1 | 47 |
| 2 | 66 |
| 3 | 110 |

A_j

| Attraction | |
|------------|----|
| 1 | 45 |
| 2 | 90 |
| 3 | 88 |

| From zones | To Zones | | | |
|------------|----------|----|----|-----|
| | 1 | 2 | 3 | |
| 1 | 10 | 18 | 19 | 47 |
| 2 | 30 | 32 | 4 | 66 |
| 3 | 5 | 40 | 65 | 110 |
| | 45 | 90 | 88 | 223 |

Tijmrsp

| | |
|-------|---|
| Edud. | 2 |
| Work | 6 |
| Other | 1 |
| | 9 |

Tijmrs (Income)

| | |
|--------|----|
| High | 3 |
| Medium | 5 |
| Low | 9 |
| | 17 |

Tijm

| | |
|---------|----|
| Mode I | 25 |
| Mode II | 15 |
| | 40 |

Tijmr

| | |
|---------|----|
| Route A | 5 |
| Route B | 17 |
| Route C | 3 |

Tijmrp

| Trip Purpose | |
|--------------|----|
| Education | 3 |
| Work | 12 |
| Other | 2 |
| | 17 |



① Trip Generation

- Aims at predicting the total number of trips generated by (O_i) and attracted to (D_j) each zone of the study area
- **Trip or Journey:** This is a one-way movement from a point of origin to a point of destination
- **Home-based (HB) Trip** This is one where the home of the trip maker is either the origin or the destination of the journey
- **Non-home-based (NHB) Trip** This, conversely, is one where neither end of the trip is the home of the traveler



Classification of Trips

- travel to work
- travel to school or college (education trips)
- shopping trips
- social and recreational journeys
- escort trips (to accompany or collect somebody else)
- other journeys



2 Trip Distribution

- The purpose of the trip distribution is to estimate 'zone to zone' movements, i.e., trip interchanges

Gravity Model

- Probability that a trip of a particular purpose k produced at zone i will be attracted to zone j , is proportional to the attractiveness or 'pull' of zone j , which depends on two factors.
- One factor is the magnitude of activities related to the trip purpose k in zone j , and the other is the spatial separation of the zones i and j .



2 Trip Distribution: Gravity Model

- The gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination.
- The calibrating term or "friction factor" (F) represents the reluctance or impedance of persons to make trips of various duration or distances.
- The general friction factor indicates that as travel times increase, travelers are increasingly less likely to make trips of such lengths.

Standard form of gravity model

$$T_{ij} = \frac{A_j F_{ij} K_{ij}}{\sum_{\text{all zones } i} A_i F_{ij} K_{ij}} \times P_i$$

Where:

T_{ij} = trips produced at I and attracted at j

P_i = total trip production at I

A_j = total trip attraction at j

F_{ij} = a calibration term for interchange ij, (friction factor) or travel time factor ($F_{ij} = C/t_{ij}^n$)

C= calibration factor for the friction factor

K_{ij} = a socioeconomic adjustment factor for interchange ij

i = origin zone

n = number of zones



3 Mode Choice

- Relates the probability of transit usage to explanatory variables in mathematical form
- **Factors Affecting Mode Choice**

Factors that may explain a trip maker's choosing a specific mode of transportation for a trip are grouped commonly as follows:

- **Trip Makers Characteristics:**
 - Income
 - Car-Ownership
 - Car Availability
 - Age
- **Trip Characteristics:**
 - Trip Purpose - work, shop, recreation, etc.
 - Destination Orientation - CBD vs. non-CBD
 - Trip Length
- **Transportation Systems Characteristics**
 - Waiting time
 - Speed
 - Cost
 - Comfort and Convenience
 - Access to terminal or transfer location



3 Mode Choice



Bus - 40 minutes



I chose
CAR



Car - 35 minutes

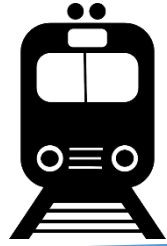
Actual Behavior – Reveled Preference (RP) Data



3 Mode Choice



Bus - 40 minutes



A new service introduced
Metro - 15 minutes



Car - 35 minutes



If new service is introduced, I will chose Metro

Hypothetical Behavior – Stated Preference (SP) Data



3 Mode Choice

- $P_{Metro} = \frac{\exp(v_{Metro})}{\exp(v_{Metro}) + \exp(v_{EM})}$

$$V_{Metro} = \alpha WT_{Metro} + \beta TT_{Metro} + \gamma TC_{Metro} + \phi DC_{Metro} + CONST$$

$$V_{EM} = \alpha WT_{EM} + \beta TT_{EM} + \gamma TC_{EM} + \phi DC_{EM}$$

$Pr (Metro/EM)$ = probability of shifting to Metro

V_{Metro} = deterministic component of utility of Metro mode

V_{EM} = Utility of Existing Mode

WT = waiting time

TT = travel time

TC = travel cost

DC = discomfort

$\alpha, \beta, \gamma, \phi$ = parameters to be estimated using SP data

$CONST$ = constant that explains the unobserved effects



4 Traffic Assignment

- Allocates the trips between each zone pair to the links comprising the most likely travel routes.
- The trips on each link are accumulated and the total trips on each link are reported at the end of the assignment process
 - All or Nothing Assignment
 - User Equilibrium



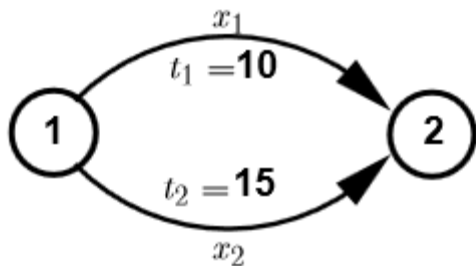
4 Traffic Assignment

All or nothing

- Trips from any origin to any destination is loaded into a single, minimum cost path between them

Limitations:

- Unrealistic as only one path is utilized
- No consideration for capacity or congestion – travel time is a fixed input



Two Link Problem with constant travel time function

and total flows from 1 to 2 is given by. $q_{12} = 12$

Since the shortest path is Link 1 all flows are assigned to it making $x_1 = 12$ and $x_2 = 0$.

User Equilibrium (UE)

- The user equilibrium assignment is based on Wardrop's first principle, which states that no driver can unilaterally reduce his/her travel costs by shifting to another route.
- UE conditions can be written for a given O-D pair as

$$f_k(c_k - u) = 0 : \forall k$$

$$c_k - u \geq 0 : \forall k$$

where f_k is the flow on path k , c_k is the travel cost on path k , and u is the minimum cost.

Equation labelqueue2 can have two states.

1. If $c_k - u = 0$, from equation 10.1 $f_k \geq 0$. This means that all used paths will have same travel time.
2. If $c_k - u > 0$, then from equation 10.1 $f_k = 0$.

This means that all unused paths will have travel time greater than the minimum cost path. where f_k is the flow on path k , c_k is the travel cost on path k , and u is the minimum cost.



Choice models



Choice Models

- Choice modelling is based primarily on the utility theory.
- Characteristics of the alternatives defines its attractiveness for a particular user
- Utility is a subjective concept but it can be useful for comparison between given alternatives.



Utility Theory

- Each alternative has attractiveness or utility associated with it
- Decision maker is assumed to choose that alternative which yields the highest utility
- Utilities are expressed as sum of measured attractiveness and a random term
- Measured attractiveness is a function of the attributes of the alternative as well as the decision maker's characteristics

$$U_{ji} = V_{ji} + \varepsilon_{ji}$$

$$V_{ji} = \beta' Z_{ji} \quad Z_{ji} = (X_{ji}, S_i)$$

Where,

U_{ji} = utility of alternative j for individual i

V_{ji} = measured attractiveness of alternative j for individual i

ε_{ji} = random part

Z_{ji} = column vector of characteristics of the individual i and attributes of the alternative j

β = column vector of parameters



Utility Theory

- The alternative j is chosen by i when

$$U_{ji} > U_{li} \quad \text{for all } l \neq j$$

- The probability P_{ji} for the j^{th} alternative to be chosen is

$$\begin{aligned} P_{ji} &= \Pr[V_{ji} + \varepsilon_{ji} > V_{li} + \varepsilon_{li}] \quad \text{for all } l \neq j \\ &= \Pr[(\varepsilon_{li} - \varepsilon_{ji}) < (V_{ji} - V_{li})] \end{aligned}$$



Variables ...

- **Generic Variable** - Variable that appears in the utility functions of all alternatives in a generic sense and has same coefficient estimate for all the alternatives
- **Alternative Specific Variable** - Variable that appears only in the utility function of those alternatives to which it is specific and has different coefficient estimate for each of the alternatives
- **Alternative Specific Constant** - Takes care of unexplained effects



Some Limitations of 4-step TDM

- Traditional travel demand models ignore travel as a demand derived from activity participation decisions
- Does not incorporate the reason for traveling – the activity at the end of the trip
- Trips treated as independent and ignores their spatial, temporal, and social interactions
- Heavy emphasis on commuting trips and Home-based trips
- Limited policy sensitivity (TAZs are hard to use in policy analysis)



Activity Based Modelling



Necessity of Activity Based Travel Demand Modelling

- Development of ABM due to poor forecasting results achieved in the trip based aggregate demand models
- Introduce - road pricing
- new technologies - (Internet and mobile phones)
- For solving urbanization problems, understanding behavioural changes of people in developing countries is necessary



Activity Based Modelling – Historical

- ABM belongs to the 3rd generation of travel demand models
 - Trip based 4-step models
 - Disaggregate trip based models (1980's & 1990's)
 - Activity based models
- In ABM the basic unit of analysis is the activities of individuals/households
- Activity Based Models (ABM) predict travel behavior as a derivative of activities (i.e., derived demand)
- Travel decisions are part of a broader process based on modeling the demand for activities rather than merely modeling trips
- ABM are based on the theories of Hägerstrand (1970) and Chapin (1974)
 - Hägerstrand focused on personal and social constraints
 - Chapin focused on opportunities and choices
- Theory is that activity demand is motivated by basic human desires for: survival, ego gratification, and social encounters



ABM Approach

- Travel demand is derived from activities that individuals need/wish to perform
- Sequence/patterns of behavior, not individual trips, are the unit of analysis
- Household and other social structures influence travel and activity behavior
- Spatial, temporal, transportation, and interpersonal interdependencies constrain activity/travel behavior
- Activity based approaches aim at predicting which activities are conducted *where, when, for how long, with whom, by mode*, and ideally also the implied *route* decision



ABM Paradigms

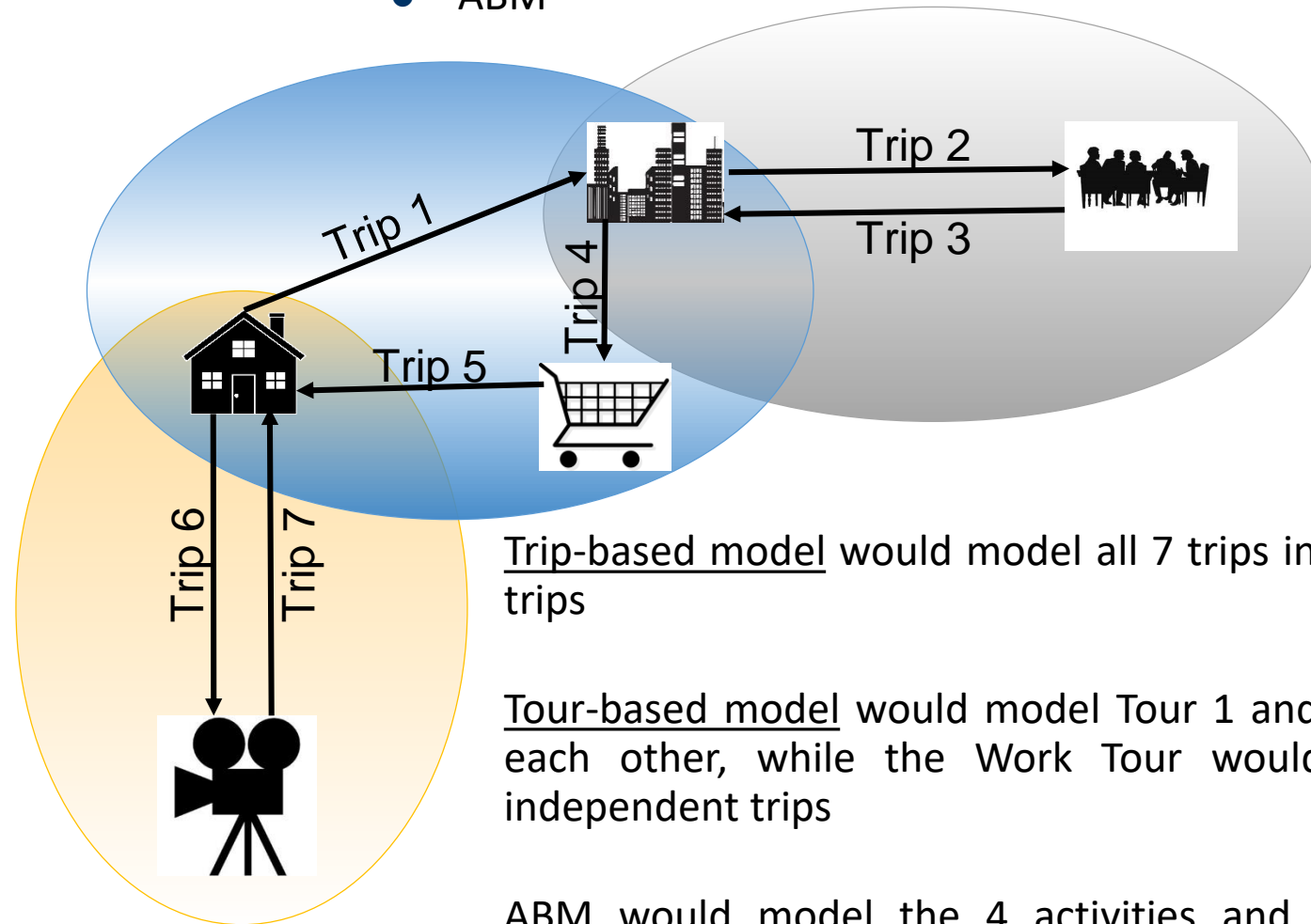
- ABM rely on the following 5 paradigms:
 - Travel derived demand from activity participation
 - Focus is on the sequence of activities
 - Activities are planned within the context of the household
 - Activities are spread over a 24-hour
 - Travel choices are limited in time, space, and by personal constraints



Modelling Trips

- Trip-based model
- Tour-based model
- ABM

Hypothetical Travel Day



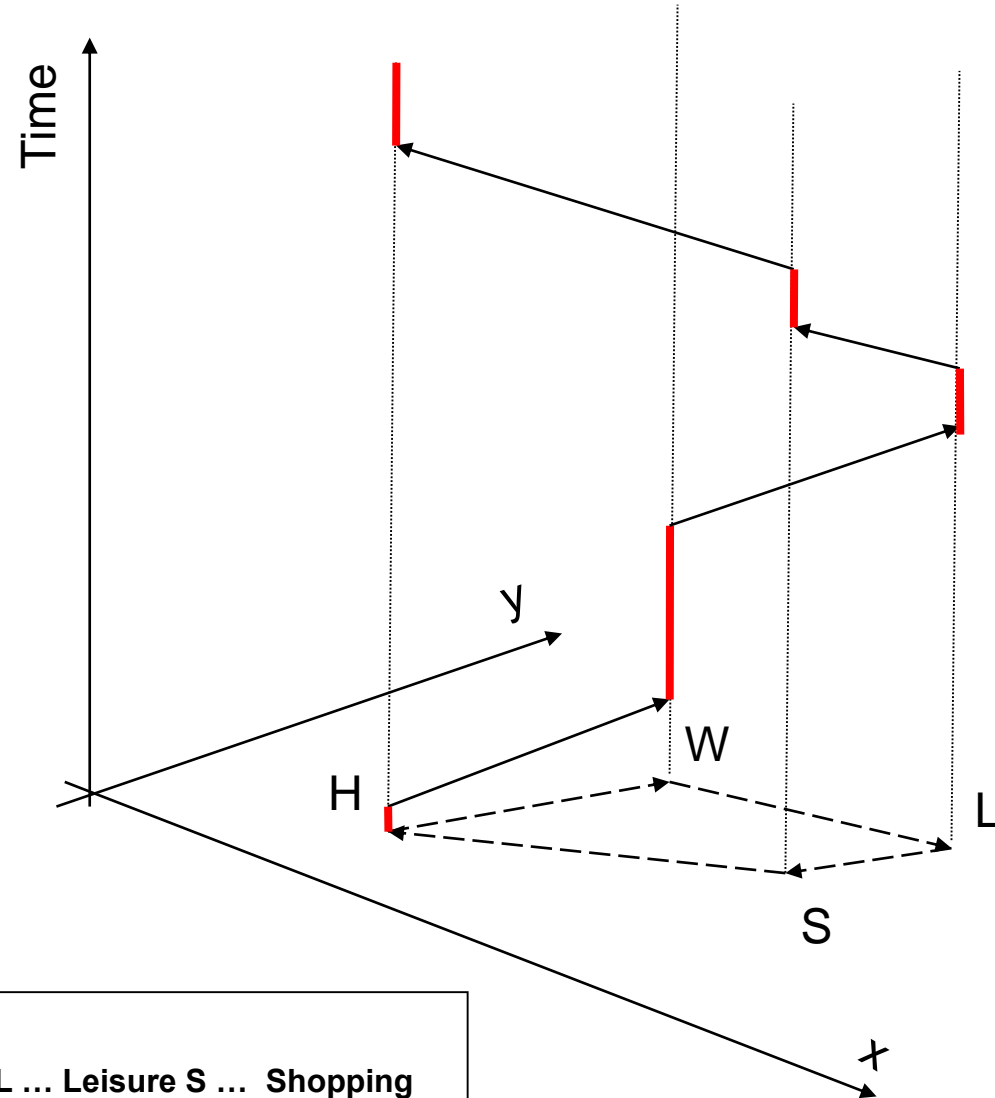
Trip-based model would model all 7 trips independent of the other trips

Tour-based model would model Tour 1 and Tour 2 independent of each other, while the Work Tour would be modeled as two independent trips

ABM would model the 4 activities and associated trips (work, meeting, shopping, and movie) as part of the same decision process



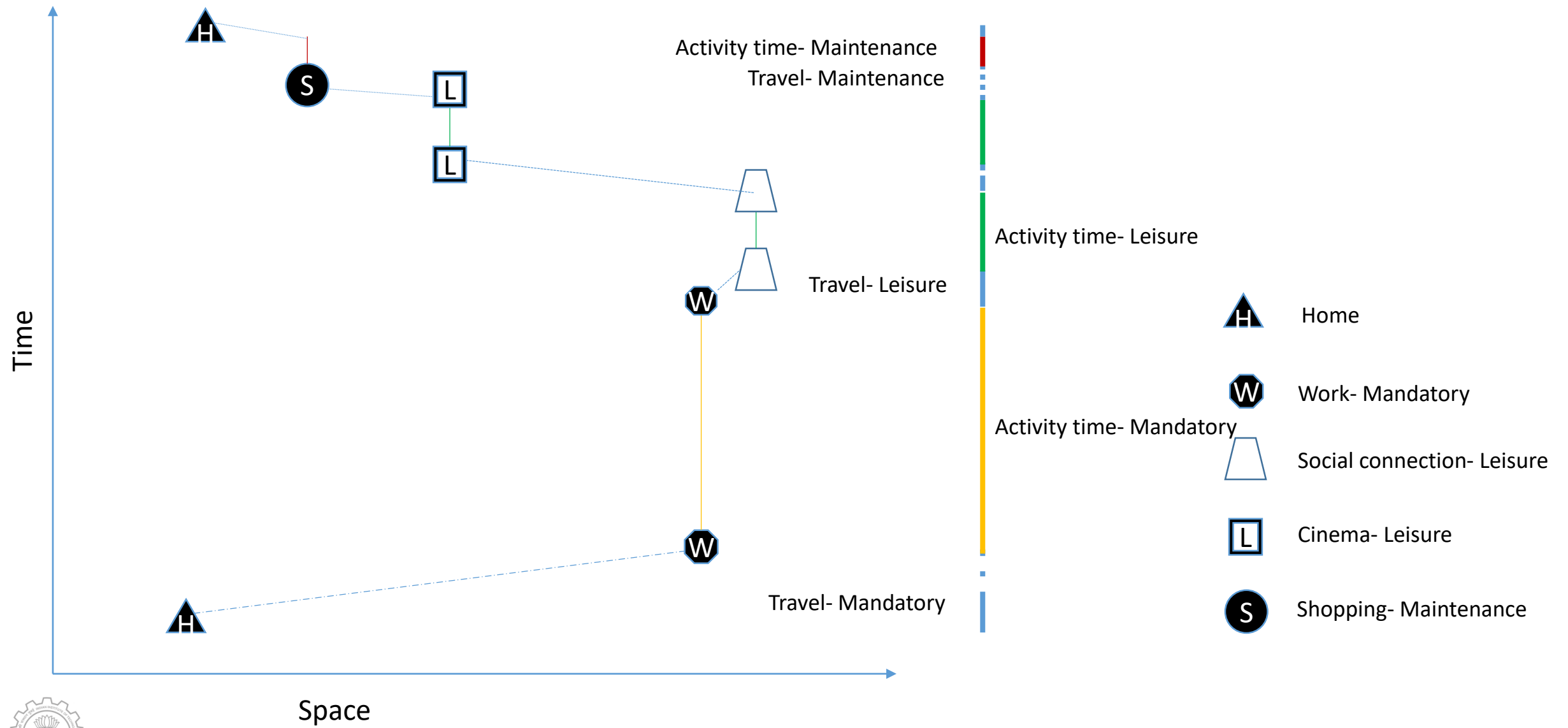
Activities in Time and Space



Activities:
H ... Home W ... Work L ... Leisure S ... Shopping



Activities in Time and Space



Criticism of Trip and Tour Based Models

Modelled as independent and isolated trips

- No-connection between the different trips
- No-time component
- No-sequential information
- No-behavioural foundation
- No-data efficient

Modelled as independent and isolated tours

- No-temporal dimension
- Independent tours, model is not capable of making the integration



Advantages of ABM

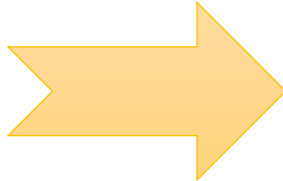
- Theoretically based on human behavior
- Better understanding and prediction of traveler behavior
- Based on decision-making choices present in the “real-world”
- Use of disaggregate data
- Inclusion of time-of-day travel choices



Activity Patterns (Schedule)

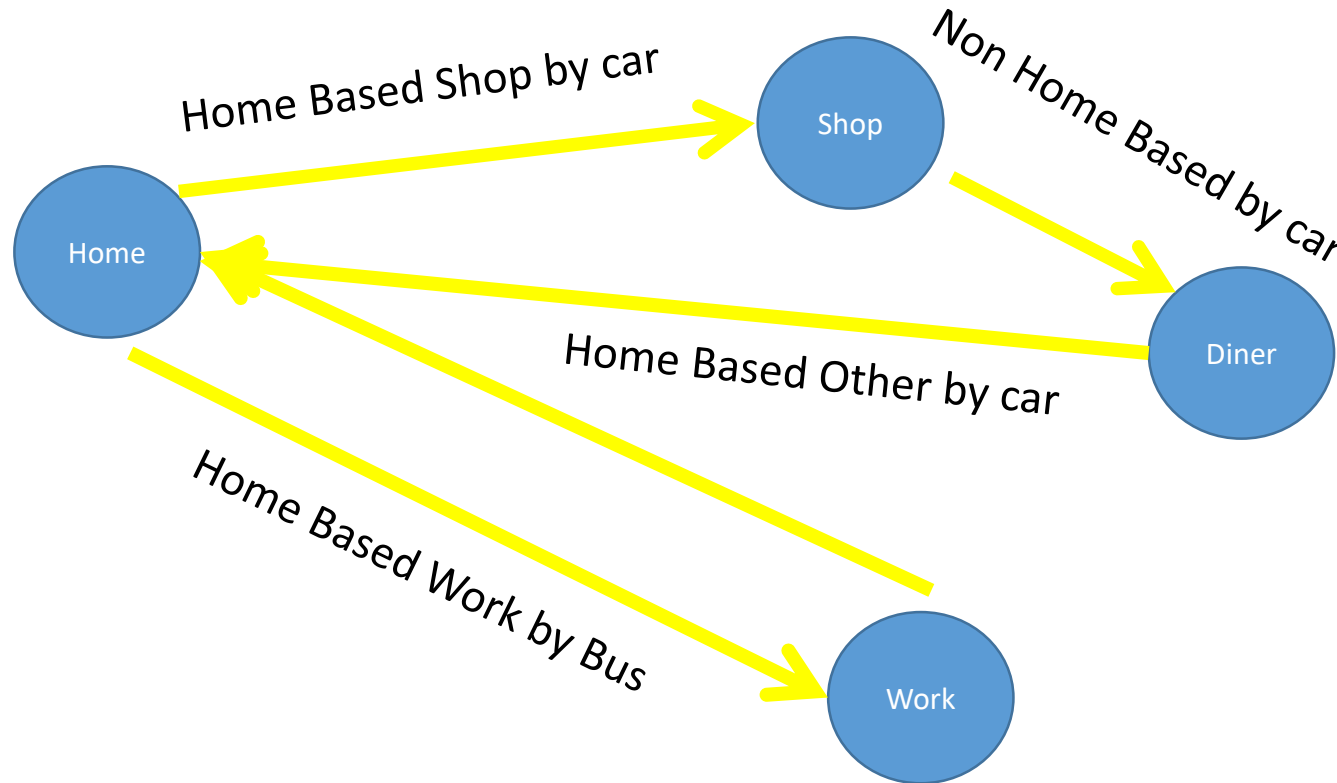
A sequence of activities, or a schedule, defines a path in space and time

What defines a person's activity pattern?

- Total amount of time outside home
 - Number of trips per day and their type
 - Allocation of trips to tours
 - Allocation of tours to particular HH members
 - Departure time from home
 - Arrival time at home in the evening
- 
- Activity duration
 - Activity location
 - Mode of transportation
 - Travel party



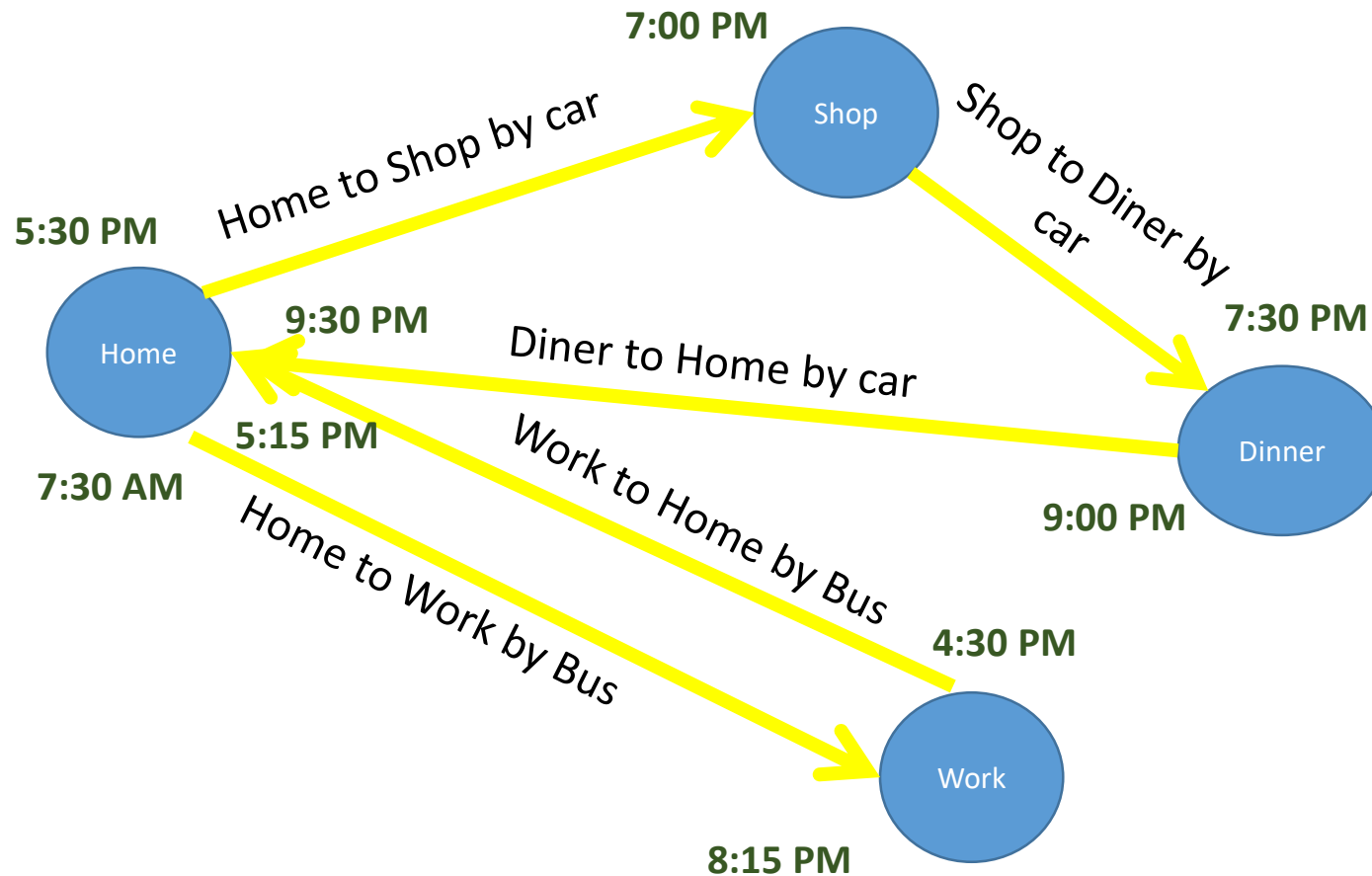
A Person's Daily Travel Pattern (conventional model)



TRIPS:
-2 HBW
-1 HBS
-1 HBO
-1 NHB



A Person's Daily Travel Pattern (activity based model)

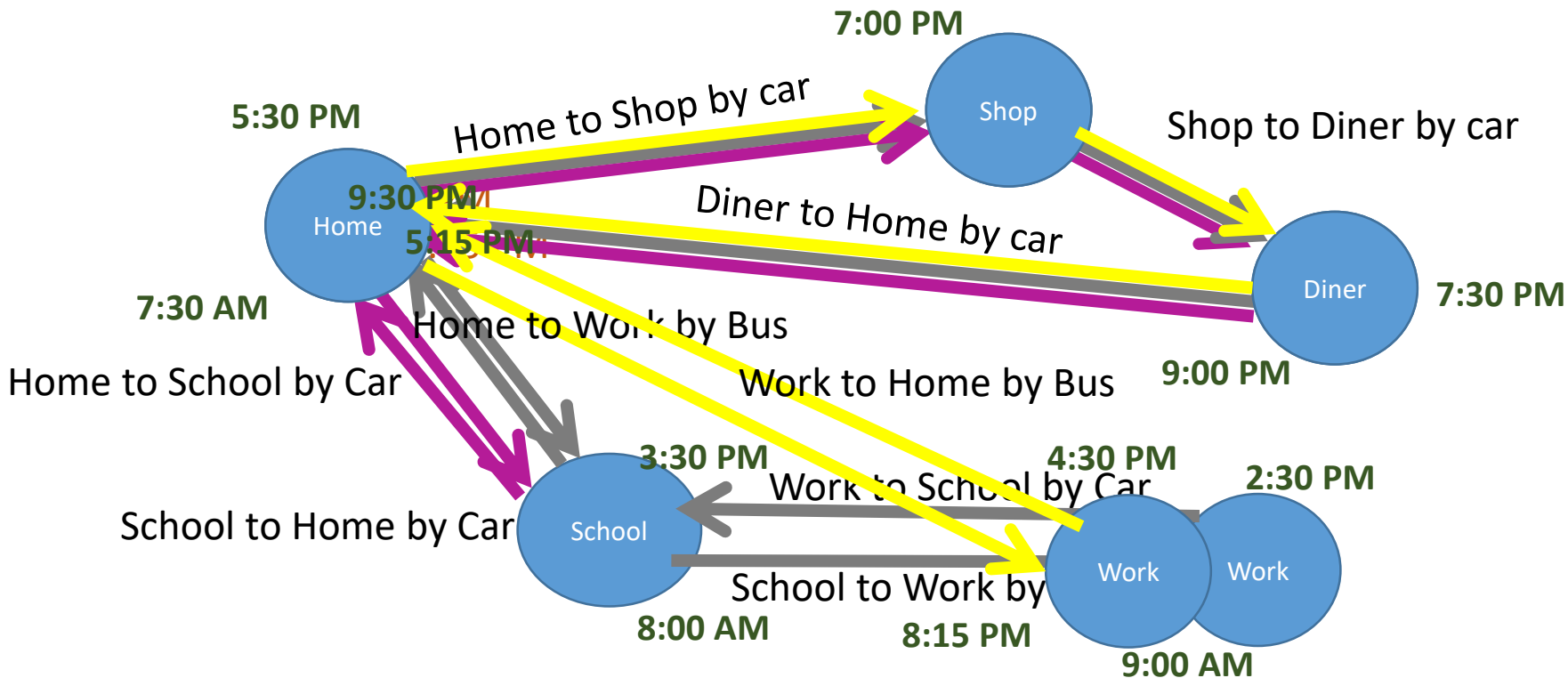


TRIPS:
-2 HBW
-1 HBS
-1 HBO
-1 NHB

-2 Home based tours
(chains)
-Timing of all trips
-Duration of activity at
each location



All Household Members' Travel Pattern (activity based model)



Some Key Aspects of Activity Based Models

- Trips are linked for each person in a day
- Timing and durations are included
- Entire daily travel patterns are linked
- Car use is associated to needs (take child to school, drive together to shop & dine and back)



Survey Instrument

- Household Information
- Person Information
- Activity Information

Activity Diary

Activities classified:

- Work related activities
- Maintenance activities
- Leisure activities



Modelling approaches

- Econometric modelling
- Rule based modelling
- Markov models
- Microsimulation modelling



CONCLUSION

- Conventional four stage-planning models for travel demand forecasting includes the lack of behavioral foundation, over dependence on trips, and insensitivity to policy changes.
- There is a need to develop the models which will take into account above criteria's to improve the travel demand.
- The new modeling approach i.e. activity based travel demand modeling has good scope in developing countries due to its more focus on behavioral aspect of people.

